IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of

Christian Joachim KEIDEL et al.

Serial No.: 10/787,257

Filed: February 27, 2004

For: METHOD FOR PRODUCING AN INTEGRATED MONOLITHIC ALUMINUM STRUCTURE AND ALUMINUM PRODUCT MACHINED FROM THAT STRUCTURE

CLAIM FOR PRIORITY

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

The benefit of the filing dates of the following prior applications filed in the following foreign countries is hereby requested for the above-identified application and the priority provided in 35 USC 119 is hereby claimed:

European Patent Application No. EP 03075764.5 filed 17 March 2003

US Provisional Patent Application No. 60/456,253 filed 21 March 2003.

In support of this claim, a certified copy of said original foreign application already in English is filed herewith.

It is requested that the file of this application be marked to indicate that the requirements of 35 USC 119 have been fulfilled and that the Patent and Trademark Office kindly acknowledge receipt of this document.

Respectfully submitted,

Date: March 26, 2004

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Bescheinigung

Certificate

Attestation

Die angehefteten Unterlagen stimmen mit der ursprünglich eingereichten Fassung der auf dem nächsten Blatt bezeichneten europäischen Patentanmeldung überein.

The attached documents are exact copies of the European patent application described on the following page, as originally filed.

Les documents fixés à cette attestation sont conformes à la version initialement déposée de la demande de brevet européen spécifiée à la page suivante.

Patentanmeldung Nr. **Patent application No.** **Demande de brevet n°**

03075764.5

Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
p.o.

R C van Dijk

Anmeldung Nr:
Application no.: 03075764.5
Demande no:

Anmeldetag:
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Anmelder/Applicant(s)/Demandeur(s):

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ALLEMAGNE

Bezeichnung der Erfindung/Title of the invention/Titre de l'invention:
(Falls die Bezeichnung der Erfindung nicht angegeben ist, siehe Beschreibung.
If no title is shown please refer to the description.
Si aucun titre n'est indiqué se referer à la description.)

Method for producing an integrated aluminium structure and aluminium product machined from that structure

In Anspruch genommene Prioriät(en) / Priority(ies) claimed /Priorité(s) revendiquée(s)
Staat/Tag/Aktenzeichen/State/Date/File no./Pays/Date/Numéro de dépôt:

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METHOD FOR PRODUCING AN INTEGRATED ALUMINIUM STRUCTURE AND ALUMINIUM PRODUCT MACHINED FROM THAT STRUCTURE

The present invention relates to a method for producing an integrated aluminium structure from an aluminium alloy, preferably selected from the group of AA7xxx, AA6xxx, AA2xxx, AA5xxx-series alloys, according to claim 1 and 2, and an aluminium product produced from an integrated aluminium structure according to claim 10. More specifically, the present invention relates to a method for producing structural aeronautical members from high strength, high toughness, corrosion resistant aluminium alloys designated by the AA7000-series of the international nomenclature of the Aluminum Association ("AA") for structural aeronautical applications. Even more specifically, the present invention relates to new methods for producing integrated aluminium structures for aeronautical applications which combine sheet and plate members within one integrated monolithic structure thereby avoiding distortion due to beneficial artificial ageing procedures.

It is known in the art to use heat-treatable aluminium alloys in a number of applications involving relatively high strength, high toughness and corrosion resistance requirements such as aircraft fuselages, vehicular members and other applications. Aluminium alloys 7050 and 7150 exhibit high strength in T6-type tempers (see e.g. US-6,315,842). Also precipitation-hardened AA7x75 and AA7x55 alloy products exhibit high strength values in the T6 temper. The T6 temper is known to enhance the strength of the alloy product and therefore finds application in particular in the aircraft industry. It is also known to artificially age the pre-assembled structures of an aircraft in order to enhance the corrosion resistance since the typical applications result in exposure to a wide variety of climatic conditions necessitating careful control of working and ageing conditions to provide adequate strength and resistance to corrosion, including both stress corrosion and exfoliation.

It is therefore known to artificially over-age these AA7000-series aluminium alloys. When artificially aged to a T79, T76, T74 or T73-type temper their resistance to stress corrosion, exfoliation corrosion and fracture toughness improve in the order stated (T73 being the best and T79 being close to T6). An acceptable temper condition is the T74 or T73-type temper thereby obtaining an acceptable balanced

level of tensile strength, stress corrosion resistance, exfoliation corrosion resistance and fracture toughness.

When producing structural parts of an aircraft such as an aircraft fuselage which consists of stringers (cabin stringers, fuselage stringers) or beams as well as skin (fuselage skin, cabin skin) it is known in the art to connect the stringers or beams to an aluminium alloy sheet, which constitutes e.g. fuselage skin, with rivets or by means of welding. An aluminium alloy sheet is bended and formed in accordance with e.g. the fuselage shape of an aircraft and connected to the stringers and beams or ribs by means of welding and/or throughout the use of rivets. The purpose of the stringers and ribs is to support and stiffen the finished structure.

In order to accelerate the production of aircraft and due to the need of reducing costs and accelerating production time it is also known to produce an aluminium alloy plate having a thickness in the range of 15 to 70 mm and to bend the plate which has a thickness equal to or greater than the thickness of the sheet constituting the aircraft fuselage skin and the height of the stringers or beams. After the bending operation the stringers are machined from the plate, thereby milling the aluminium material from in between the stringers.

Such prior art techniques display at least two major disadvantages. Firstly, the plate, which has been produced from an aluminium alloy which has been artificially aged as mentioned above in order to enhance the corrosion resistance, displays considerable distortion after the bending and machining operation thereby showing a vertical and horizontal distortion which makes the assembly of the aircraft fuselage or aircraft wing cumbersome since all parts need additional correction bending and measurement operations. Secondly, the bended and machined structure comprising sheet and stringers/beams displays residual or inner stress coming from the bending operation and resulting in regions having a microstructure different from other regions with less or more internal residual stress. Those regions with an elevated level of internal residual stress tend to be more susceptible to corrosion and fatigue crack propagation.

It is therefore the object of the present invention to provide methods for producing an integrated monolithic aluminium structure and an aluminium product machined from that structure which does not have one or more of the aforementioned

disadvantages thereby providing structural members for aircraft or other applications which are easier and inexpensive to assemble, which display no or only few distortion and which have a uniform microstructure thereby avoiding regions of differing inner stress levels.

More specifically, it is the object of the present invention to provide a method for producing an integrated monolithic aluminium structure for aeronautical applications which may be used to assemble an aircraft faster than with prior art aluminium structures and by achieving better properties such as strength, toughness and corrosion resistance.

The present invention meets these objects by the features of each of claim 1 and 2. Further preferred embodiments are described and specified within the sub-claims. An aluminium product produced from an integrated aluminium structure which has been produced in accordance with the method according to the invention is set out in claim 10. Preferred embodiments are described and claimed in the corresponding sub-claims.

As will be appreciated hereinbelow, except otherwise indicated, alloy designations and temper designations refer to the aluminium association designations in Aluminium Standards and Data and the Registration Records, all published by the US Aluminum Association.

The above mentioned objects of the present invention are achieved by preparing an aluminium alloy plate from an aluminium alloy with a predetermined thickness, shaping said alloy plate to obtain a predetermined shaped structure, preferably thereafter artificially or naturally ageing or annealing said shaped structure and then milling or machining, e.g. via high velocity machining, said shaped structure in order to obtain an integrated monolithic aluminium structure which can be used for the aforementioned purposes.

Since the ageing step or annealing is performed after the shaping step it is possible to obtain structural members having considerable reduced levels of distortion or are even essentially distortion-free making the resultant products suitable for aircraft fuselage or wing applications or a vertical skin with vertical spars for the tale of an aircraft. It is believed that said shaped structure, which displays the aforementioned disadvantages due to the shaping step, releases its inner stress or

residual throughout the artificially or naturally ageing step which is performed after the shaping step of the alloy plate.

In a preferred embodiment of the method according to the invention after the shaping operation of the aluminium alloy plate into a predetermined shaped structure after prior to any machining operation, e.g. high velocity machining, the shaped structure is being artificially aged resulting in an improved dimensional stability during machining operations. Preferably the shaped structure is being artificially aged to a temper selected from the group comprising T6, T79, T78, T77, T76, T74, T73 and T8 temper condition. By means of example, a suitable T73 temper would be the T7351 temper.

In an embodiment of the method the shaping or forming process to obtain a predetermined shaped structure comprises a cold forming operation, e.g. a bending operation resulting in a product having a built in radius.

In an embodiment of the method according to the invention the aluminium alloy plate prior to the shaping or forming operation has been stretched after quenching from the solution heat-treatment temperature. Preferably the stretching operation involves not more than 8% of the length prior to the stretching operation, and is preferably in a range of 1 to 5%. Typically this is achieved by bringing the aluminium alloy plate in a T4 or a T73 or T74 or T76 temper, such as a T451 temper or a T7351 temper.

The shaped structure has preferably a pre-machining thickness equal or greater than the combined thickness of a base sheet (skin) and additional components (stringers) wherein said base sheet and additional components form said integrated aluminium structure.

In an embodiment the pre-machining thickness (y) of the shaped structure is in the range of 10 to 220 mm, preferably in the range of 15 to 150 mm, and more preferably in the range of 20 to 100 mm, and most preferably in the range of 30 to 60 mm.

The aluminium alloy plate is preferably prepared from an aluminium alloy selected from the group consisting of AA5xxx, AA7xxx, AA6xxx and AA2xxx-series aluminium alloys. Particular examples are those within the AA7x50, AA7x55, AA7x75, and AA6x13-series aluminium alloys, and typical representatives of these

series are AA7075, AA7475, AA7010, AA7050, AA7150 and AA6013 alloys.

In accordance with a preferred embodiment of the present invention the aluminium alloy plate is prepared from an aluminium alloy which has been stretched after quenching. An example is given as follows:

A preferred method for producing an AA7xxx-series aluminium alloy for plate applications in the field of aerospace with balanced high toughness and good corrosion properties comprises the steps of working a body having a composition consisting of, in weight%:

Zn:	5.0 - 8.5
Cu:	1.0 - 2.6
Mg:	1.0 - 2.9
Fe:	< 0.3, preferably < 0.15
Si:	< 0.3, preferably < 0.15,

optionally one or more elements selected from

Cr:	0.03 – 0.25
Zr:	0.03 - 0.25
Mn:	0.03 - 0.4
V:	0.03 - 0.2
Hf:	0.03 - 0.5
Ti:	0.01 – 0.15,

the total of said optional elements not exceeding 0.6 weight%, the balance aluminium plus incidental impurities (each <0.05%, total <0.20%), solution heat treating and quenching the product, stretching the quenched product by 1% - 5%, preferably 1.5% - 3% to arrive at a T451 temper, and thereafter shaping the product (bending, pre-curving or milling) in order to obtain the predetermined shaped structure.

The predetermined shaped structure is then preferably artificially aged by either heating the product up to three times in a row to one or more temperatures from 79°C to 165°C or heating the predetermined shaped structure first to one or more temperatures from 79°C to 145°C for two hours or more or heating the shaped structure to one or more temperatures from 148°C to 175°C. Thereafter, the shaped structure does not display any distortion and - at the same time - the shaped structure

shows an improved exfoliation corrosion resistance of "EB" or better with about 15% greater yield strength than similar sized AA7x50 counter-parts in the T76-temper condition.

According to AMS 2772C typical ageing practice to arrive at the T7651 temper for the AA7050 alloy involves 3 to 6 hours at 121°C followed by 12 to 15 hours at 163°C, whereas for the same alloy arriving at the T7451 temper involves 3 to 6 hours at 121°C followed by 20 to 30 hours at 163°C. Typical ageing practice to arrive at the T7351 temper for the AA7475 alloy involves 6 to 8 hours at 121°C followed by 24 to 30 hours at 163°C. And typical ageing practice for the AA7150 alloy to arrive at the T651 temper involves 24 hours at 121°C or 24 hours at 121°C followed by 12 hours at 160°C.

In a preferred embodiment of the product according to the invention, the said base sheet is a fuselage skin of an aircraft and said components are at least parts of stringers or other reinforcements of the fuselage of an aircraft.

In another embodiment said base sheet is the base skin of an integrated structure like an integrated door and said components are at least parts of the reinforcements of the integrated structure of an aircraft.

In another embodiment said base sheet is a wing skin of an aircraft, said components are at least parts of ribs or other reinforcements of a wing of an aircraft.

The foregoing and other features and advantages of the inventive method and inventive aluminium product according to the present invention will become readily apparent from the following detailed description of an embodiment as further described throughout the appended drawings:

Fig. 1	shows an integrated aluminium structure,
Fig. 2	shows distortion effects of the integrated aluminium structure of Fig. 1,
Fig. 3a	shows an embodiment of the prior art,
Fig. 3b	shows an embodiment of the present invention, and
Fig. 3c	shows a shaped structure (5) artificially or naturally aged in accordance with the present invention.

Fig. 1 shows an integrated aluminium structure comprising a base sheet 1 and additional components 2 such as stringers or beams for aircraft applications. The

integrated aluminium structure 6 consists of a pre-curved base sheet 1 which is shaped in accordance with the shape of e.g. an aircraft fuselage, thereby showing the cross-section of a fuselage skin 1. The additional components 2 are e.g. stringers attached to the base sheet 1 - in accordance with prior art techniques - by rivets and/or throughout welding.

Fig. 2 shows the distortion effects of an integrated aluminium structure which has been produced in accordance with a prior art method. When the additional components 2 are attached to the base sheet 1 and when the whole structure is finished after the machining/riveting or welding step, a horizontal distortion d_1 and/or a vertical distortion d_2 usually results from stress relief from the pre-curved plate or sheet which has been bended before additional components 2 are fixed to the base sheet 1 or before components 2 are machined from a plate product with a corresponding thickness.

Fig. 3a shows an integrated monolithic structure or component manufactured also according to the prior art. An aluminium alloy block 3 is produced throughout casting, homogenising, hot working by rolling, forging or extrusion and/or cold working, solution heat treatment, quenching and stretching, thereby obtaining a thick aluminium alloy block 3 which is "shaped" to obtain a predetermined shaped structure 5. The shaping step is a mechanical milling or machining step thereby milling the aluminium alloy block 3 and obtaining a predetermined shaped structure 5 with a predetermined thickness y as shown in Fig. 3c. The predetermined thickness y is equal or greater than the sheet thickness x of the base sheet 1 and the extension of the additional components 2 which are - by a second milling step - machined from the shaped structure 5 after the ageing step. A problem with this approach is that there may be significant residual stress in the product, and this may lead to increasing the cross-section of frame members or the skin itself to meet required tolerances and safety requirements.

Fig. 3b shows an embodiment of the present invention wherein the shaping step is a mechanical bending step thereby bending an alloy plate 4 into a bended or pre-curved structure 5 shown in Fig. 3c. Using the method according to this invention also double-curved structures can be made, e.g. having a parabolic structure. An advantage of this embodiment of the present invention compared to the

prior art described under Fig. 3a is amongst others that less aluminium is used for machining or milling since the predetermined thickness y of the alloy plate 4 is considerable smaller than a predetermined thickness of the whole aluminium block 3. By an ageing step after the shaping, it is possible to obtain essentially distortion-free structural members suitable for e.g. aircraft fuselage and wing applications. Another advantage of the method and the product of the present invention is that it provides a thinner final monolithic product or structure which has strength and weight advantages over thicker type products produced over conventional methods. This means that designs with thinner walls and less weight may be provided and approved for use. Another advantage of the method and the product of the present invention is the weight reduction of the monolithic part. Weight is reduced also by the possible elimination of fasteners. This is related to the accuracy advantages in the machining operation resulting from the reduced distortion, and the inherent accuracy of final machining after forming.

Example.

On an industrial scale thick plates have been manufactured of the AA7475 alloy (aerospace grade material) having final dimensions of 40 mm thickness, a width of 1900mm, and a length of 2000mm. Different plates have been brought to the T451 temper condition and the T7351 temper condition.

In one method of manufacturing integrated structures, a plate in the T451 temper has been bended in its L-direction to a structure with a radius of 1000 mm followed by artificial ageing to the T7351 temper. The distortion in the longitudinal direction was in the range of 0.07-0.09 mm, which can be calculated in a known manner to a residual stress in longitudinal direction in the range of 16-22 MPa.

In another method of manufacturing integrated structures, a plate in the T7351 temper has been bended in its L-direction to a structure with a radius of 1000 mm without further ageing treatment. The distortion in the longitudinal direction was in the range of 0.15-0.22 mm, which can be calculated in a known manner to a residual stress in longitudinal direction in the range of 49-54 MPa. For both methods the distortion after machining has been measured in accordance with the BMS 7-323D, section 8.7, incorporated herein by reference.

This example shows amongst others the beneficial influence of the ageing treatment after forming a curved panel and prior to machining into an integrated structure on the distortion after machining and thereby on the residual stresses in the material.

CLAIMS

1. Method for producing an integrated monolithic aluminium structure, comprising the steps of:
   a.) providing an aluminium alloy plate (4) from an aluminium alloy with a predetermined thickness (y),
   b.) shaping or forming said alloy plate (4) to obtain a predetermined shaped structure (5),
   c.) machining said shaped structure (5) in order to obtain an integrated monolithic aluminium structure (6).
   d.) optionally further processing, e.g. welding, riveting or bending.

2. Method for producing an integrated monolithic aluminium structure, comprising the steps of:
   a.) providing an aluminium alloy plate (4) from an aluminium alloy with a predetermined thickness (y),
   b.) shaping or forming said alloy plate (4) to obtain a predetermined shaped structure (5),
   c.) heat-treating said shaped structure (5),
   d.) optionally machining said shaped structure (5) in order to obtain an integrated monolithic aluminium structure (6).

3. Method according to claim 2, wherein said heat treatment under step c) comprises natural ageing, artificial ageing or an annealing treatment.

4. Method according to claim 3, wherein said shaped structure (5) is being artificially aged to a T6, T79, T78, T77, T76, T74, T73 or T8 temper condition.

5. Method according to any one of claims 1 to 4, wherein the shaping or forming process during step b) comprises cold forming.

6. Method according to any one of claims 1 to 5, wherein said aluminium alloy

plate (4) has been stretched after quenching prior to the shaping or forming step.

7. Method according to any one of claims 1 to 5, wherein said aluminium alloy plate (4) is produced from an aluminium alloy which is selected from the group of AA5XXX, AA7XXX, AA6XXX or AA2XXX-series.

8. Method according to any one of claims 1 to 7, wherein said shaped structure (5) has a pre-machining thickness (y) in the range of 10 to 220 mm, and preferably in the range of 15 to 150 mm.

9. Method according to any one of claims 1 to 8, wherein the integrated monolithic aluminium structure is part of a wing skin or a frame portion for an aircraft.

10. Aluminium product produced from an integrated aluminium structure (6) produced in accordance with the method according to any one of claims 1 to 9, characterized in that, said shaped structure (5) is machined in order to obtain an integrated aluminium structure (6) with a base sheet (1) and components (2).

11. Aluminium product according to claim 10, wherein said base sheet (1) is a fuselage skin of an aircraft and said components (2) are at least parts of stringers or other reinforcements of the fuselage of an aircraft.

12. Aluminium product according to claim 10, wherein said base sheet (1) is the base skin of an integrated structure like an integrated door and said components (2) are at least parts of the reinforcements of the integrated structure of an aircraft.

13. Aluminium product as claimed in claim 10, wherein said base sheet (1) is a wing skin of an aircraft, said components (2) are at least parts of ribs or other reinforcements of a wing of an aircraft.

ABSTRACT

The present invention relates to a method for producing an integrated monolithic aluminium structure, comprising the steps of: (a) providing an aluminium alloy plate from an aluminium alloy with a predetermined thickness (y), (b) shaping or forming said alloy plate to obtain a predetermined shaped structure, (c) heat-treating said shaped structure, (d) machining, e.g. high velocity machining, said shaped structure in order to obtain an integrated monolithic aluminium structure (6). Preferably the product is subjected to an the ageing step after the shaping step, thereby resulting considerable reduced distortion, making the product suitable for structural members for aircraft fuselage or wing applications.

Fig. 1

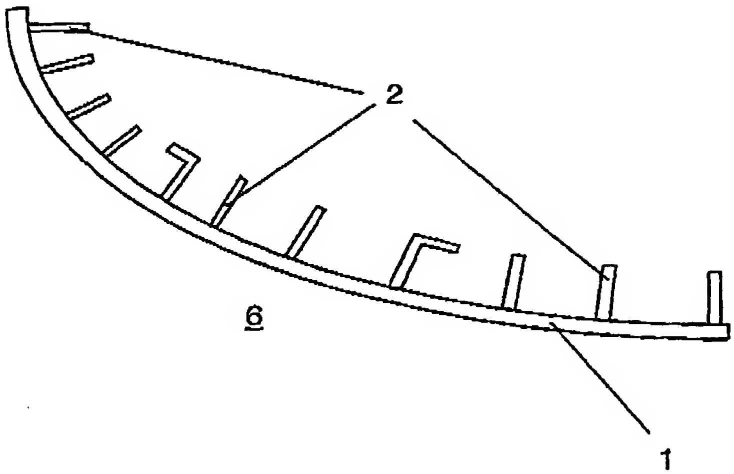

Fig. 2

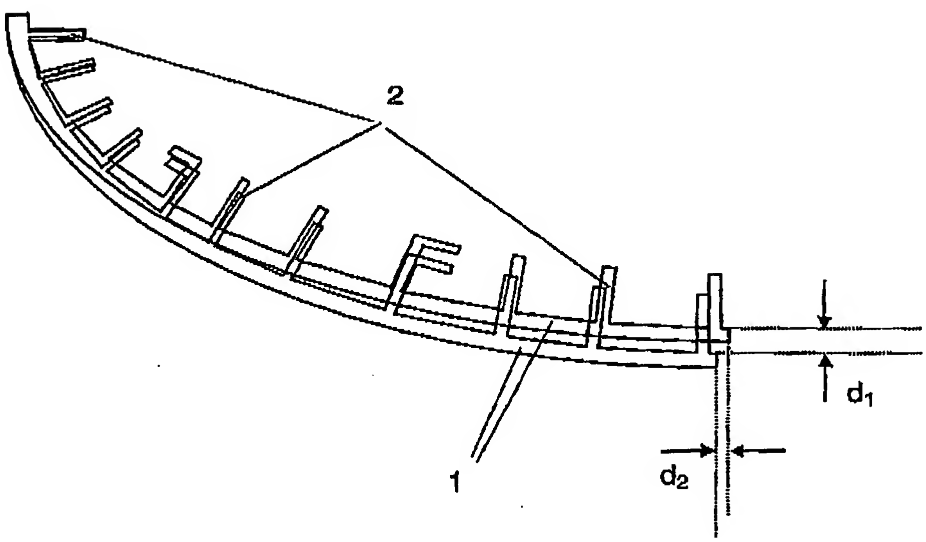

Fig. 3a

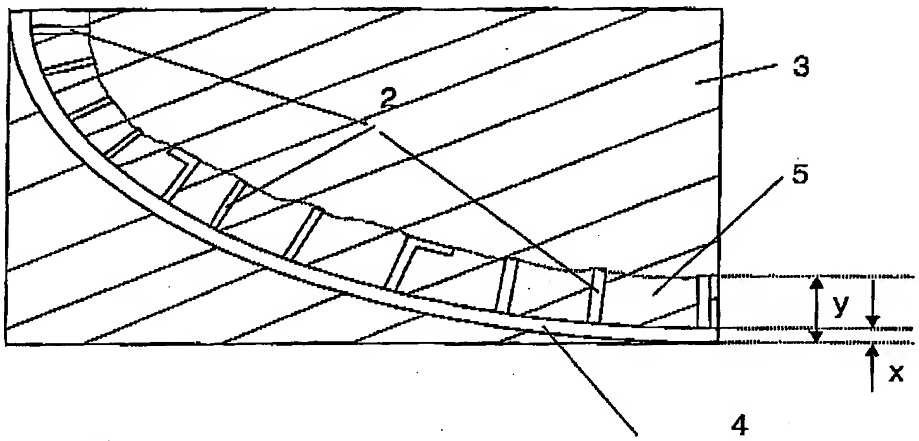

Fig. 3b

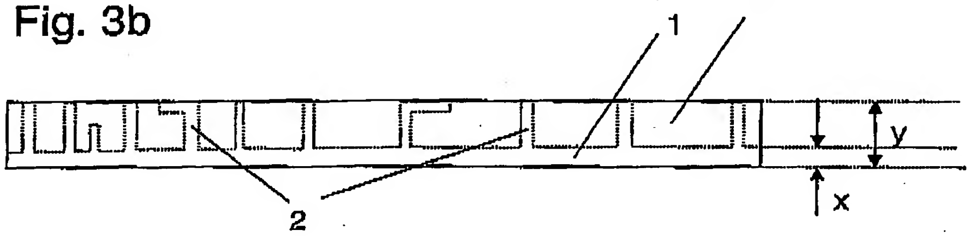

Fig. 3c